IMPORTANCE OF METEOROLOGICAL DATA IN ENGINEERING.

[Read before the Engineers Club of Philadelphia, Pa., by Geo. S. Bliss, Section Director, Weather Bureau.]

The increasing use of meteorological data by the great industrial interests of the country during the last five or six years has been remarkable. The conduct of business with due regard to the effects of weather changes and of general climatological conditions is rapidly coming to be recognized as not only convenient but decidedly profitable. This is true to a greater or less extent in practically all lines of industrial activity, and much of the permanent benefits accrue through its application to certain classes of engineering work.

Our progress during the last decade in the development of hydroelectric power, in irrigation and drainage work, in the installation of adequate and efficient water-supply systems for the larger cities, and in the improvement of our waterways has been phenomenal, and it is apparent that we are entering upon an age of growth and development along all these lines such as the world has never known. No engineering scheme covering any phase of this work can be intelligently formulated unless full consideration is given to the meteorological conditions inherent in the locality.

The agricultural engineer, a combination of engineer and scientific agriculturist, is now coming into prominence in this country. The successful conduct of his work demands a continuous use of meteorological records as well as an intelligent application of many of the known laws of atmospheric physics. Thus in addition to being an engineer and a scientific agriculturist, he must be something of a meteorologist. In the mountainous portions of the country, and especially in the large fruit-growing districts, the matter of air drainage has become equally as important as that of water drainage.

The city engineer should take into account not only the average precipitation for his locality, but also the excessive rate of rainfall on unusual occasions, and should plan his drainage accordingly. The overflowing of water from the streets into basements and the bursting of sewers during heavy rains have frequently emphasized the need for more careful computations in these matters.

It used to be customary, in the construction of railroads and highways, to install such bridges and culverts as the judgment of the engineer dictated, and then later to build larger and more substantially at those points where washouts proved the inadequacy of the first structures. Much of this inconvenience and expense is now being avoided by an intelligent consideration of rainfall records in connection with the topography of the country.

The use of meteorological records by the engineering profession became so great that in 1909 the Chief of the United States Weather Bureau decided to compile and publish all data by drainage areas instead of by State boundaries as had formerly been done. Beginning with July of that year he divided the country into 12 districts, comprising the 12 principal drainage systems, and appointed a district editor in each to compile and summarize the records for publication. As now issued, the data for each drainage area comprises a separate of the National Monthly Weather Review. These separates may be obtained by interested persons upon request and without cost, while a subscription price is usually charged for the complete Review.

The launching of a great reclamation project requires first of all a careful estimate of the agricultural possibilities of the region in question, in order to determine what would be a reasonable expenditure in carrying out the work. This estimate must include several factors, chief of which pertains to the climatological features not only of the district which it is proposed to reclaim but of the drainage basin which is to furnish the water supply. It is especially important to determine with reasonable accuracy the run-off from the drainage basin during the driest and wettest years. The agricultural value of the reclaimed area will depend not merely upon its topography and the quality of its soil but also upon the usual conditions of temperature, wind, and sunshine, the rainfall in this case being of secondary importance. The average length of the growing season, or the average time between the last damaging frost of spring and the first of autumn, must be considered at all events.

Irrigation, drainage, and the development of hydroelectric power are often intimately associated by combining facilities for subsurface irrigation with those of tile drainage, and by installing power plants at the retaining dams of great irrigation systems. Tile drainage has been found to be almost as beneficial in dry seasons as in wet ones, and more land has been reclaimed by drainage than by irrigation. It may also be mentioned that in some places hydroelectric power is being used to pump or elevate water for irrigating purposes to points that would otherwise be inaccessible.

In addition to the large field, as outlined, in which the meteorological data are of prime importance, it may be suggested that the rainfall records offer an opportunity for the engineer to greatly enlarge his field of activites. A careful study of the rainfall records for the United States reveals the fact that there are few, if any, agricultural districts in which the rains are so dependable as to make irrigation unnecessary or unprofitable. Almost invariably there occurs a period during each growing season when the deficiency of moisture is such as to check the growth of vegetation. Irrigation at such times would greatly increase the production and might double or triple the yield, or even produce a good crop where practically all would otherwise have been lost. With the demands for produce rapidly outstripping the supply, more intensive methods of agriculture are becoming imperative in this country, and facilities for irrigation form the chief problem in this connection.

Many valleys offer opportunities to lead water from streams at the upper reaches and conduct it in flumes along the hillsides above the land to be irrigated. In other places it may be necessary to elevate the water by hydraulic power, and in still others wind power may be utilized for large pumping operations. All of these problems are for the engineer and in fostering and developing them he can make extensive use of the meteorological data that can be supplied by the United States Weather Bureau.

Data for a definite locality may often be unobtainable, but in this country they can usually be interpolated with sufficient accuracy from nearby points where records have been kept. An instance of how this can be done may be cited in the Los Angeles water project, which ranks among the greatest engineering feats that have been accomplished by municipalities. When it was proposed to bring water to Los Angeles from the Owens Valley, a distance of 200 miles over mountains and deserts, it

became necessary to ascertain the water resources of the valley. Old precipitation records were not available from a sufficient number of points to establish the average rainfall as well as the extremes for the valley, and to determine its relation to the run-off.

Rain gages were therefore located at numerous points and their catchment for several months was prorated with that of the permanent gages. The application of these ratios to the older records formed a satisfactory solution of the problem. The flow of the small mountain streams was also measured and it was found that seepage and evaporation are so great that only 15 per cent of the precipitation finally reaches the Owens River.

The United States Weather Bureau maintains something over 200 stations at which complete meteorological records are kept. In addition to this there are more than 4,000 cooperative stations equipped with standard thermometers and rain gages. Consequently there are few localities more than 75 to 100 miles from a regular Weather Bureau station, while temperature and precipitation records are available at one or more places in nearly every county.

At a majority of the stations the records cover periods of 10 years or more, and in nearly every State there are several points at which they have been kept for 30 years or upward. Usually a 10-year mean will vary less than 10 per cent from a 30-year mean, and 10 years of complete data may be depended upon to include the extremes except those rare occurrences which become matters of historic comment.

Copies of most of the records for the whole country are on file at all the larger Weather Bureau stations, but that fact is not so generally known as it should be. Nearly every engineer who has visited the Philadelphia office has commented about the large amount of meteroological statistics available.

At present we are recording precipitation measurements at about 100 places in Pennsylvania, mostly in small towns along the railroads and in the valleys. It is my belief that the number of stations should be nearly doubled, the increase being distributed wherever possible over the higher ridges and the headwaters of the principal streams. Precipitation records are to become such an important factor in our industrial development of the near future that there is little danger of accumulating excessive or unnecessary data of this character.

The Weather Bureau data comprise not only the ordinary records of temperature, precipitation, wind, and sunshine, but also gage records of all the principal streams. These river gage records are indispensable in calculating the run-off for a given drainage area, or for determining its relation to the precipitation. During the last few years the bureau has maintained a large number of special snowfall stations in mountain districts of the far West, and thus reliable information is furnished regarding the reserve water supply for many power plants and irrigation operations.

In closing I wish to express my belief that in the future the hydroelectric and the agricultural engineers are to become the leaders of the profession, the opportunities of the agricultural engineers especially being practically unlimited, and their efficiency, in no small measure, depending upon their ability to make intelligent use of meteorological data.